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METEOROLOGICAL PROBABILITIES
for
PLANNING CARRIER TASK FORCE OPERATIONS
in the
NORTH PACIFIC

U. S. NAVY WEATHER RESEARCH FACILITY
BUILDING R-48, U. S. NAVAL AIR STATION
NORFOLK 11, VIRGINIA

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FOREWORD

The purpose of Task 9, assigned to the Navy Weather Research Facility by the Chief of the Bureau of Naval Weapons, is to develop forecasting rules for specified strategic and tactical areas.

Consequently, in this report combinations of three observed weather elements and an oceanographic parameter were classified as being favorable for or adverse to carrier task force operations, after consulting with carrier task force operation personnel to establish pertinent criteria. The weather log of each North Pacific ship station over a period of years was translated into a record of "favorable" and "adverse" carrier task force operational weather. Finally, this record was summarized in two convenient graphical presentations with descriptions included for application by Navy weather personnel.

Among those who aided in the study, Commander W. L. Somervell, Jr., USN, was responsible for establishing the original criteria used in summarizing the data, and Mr. Hermann B. Wobus provided technical council. Mr. S. Donald Case, Jr., leader of Task 9, developed the computer programs utilized in the computations, supervised the work, and wrote the manuscript for this report. Mr. John M. Mercer performed the final edit.

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1. INTRODUCTION

1.1 Providing Requirements for Operational Planning

Planning carrier task force manuevers often requires that weather elements and sea state be considered along with other parameters. However, the planner who desires to take them into account often encounters difficulty; usually there are no observational data pertaining to the oceanic area of interest upon which to base a firm decision. The data that does exist frequently must be processed and refined in order to extract from them information which is pertinent to operational planning.

When no data are available, inferences frequently may be obtained from data gathered at adjacent oceanic localities. As a rule, however, the quality of the inferred data depends upon the distance from the point of observation and is most reliable at the observation station, growing gradually less reliable with distance. The Navy has devoted considerable time to the problem of refining and summarizing meteorological data in order to render them more generally useful for operational planning. The "U. S. Navy Climatic Atlas of the World" and "Meteorological Probabilities for Planning Task Force Operations in the North Atlantic" (NWRF 13B-0959-027) partially fulfill the need for appropriate summaries for the planner. This study is intended to serve as a counterpart for the latter publication, and in a like manner summarizes pertinent data in a form directed toward those planning carrier task force operations in the North Pacific.

To this end, ceiling height, visibility, wind speed, and sea state were classified in combinations as being favorable for or adverse to carrier task force operations. A difficulty in summarizing environmental data for operational problems often exists because each operation has its own requirements. Thus, the environmental conditions applying to a carrier employing one type of aircraft may not be valid when another type of aircraft is employed. The operational criteria governing the "favorable" and "adverse" categories herein are deemed valid for most carrier air operations. However, parameter limits selected for this investigation are given, and the manner in which they were combined is explained fully in order that the planner may avoid applying the results blindly. Graphical presentations and descriptions are furnished, and the use of the graphs in planning carrier task force operations is pointed out.

1.2 Scope of Data and Operational Criteria

Weather elements of ceiling, visibility, wind force, and sea state in each 3-hourly observation gathered by North Pacific Ocean reporting vessels (see fig. 1.1 and table 1.1) were assigned to categories (i.e., operable, marginal, and inoperable) set forth in table 1.2.

TABLE 1.1.
North Pacific Ship Locations.

SHIP	LOCATION	DATA SPAN
PAPA	50° N. - 145° W.	1948 - 1958
NECTAR	30° N. - 140° W.	1946 - 1949
OBOE	40° N. - 142° W.	1949 - 1950
QUEBEC	43° N. - 167° W.	1952 - 1953
SIERRA	48° N. - 162° E.	1950 - 1952
UNION	26° N. - 149° W.	1951 - 1953
VICTOR	33° N. - 164° E.	1951 - 1956
TANGO	29° N. - 135° W.	1948 - 1953
EXTRA	39° N. - 153° W.	1948 - 1952

TABLE 1.2.
Categorical Limits for Assignment of Elements.

	CEILING	SEA HEIGHT	VISIBILITY	WIND FORCE
Operable:	above 2,000 ft.	below 5 feet	above 3 mi.	6 to 27 kts.
Marginal:	300 ft. to 2,000 ft.	5 to 12 feet	1 to 3 mi.	28 to 40 kts. and below 6 kts.
Inoperable:	below 300 ft.	above 12 feet	below 1 mi.	above 40 kts.

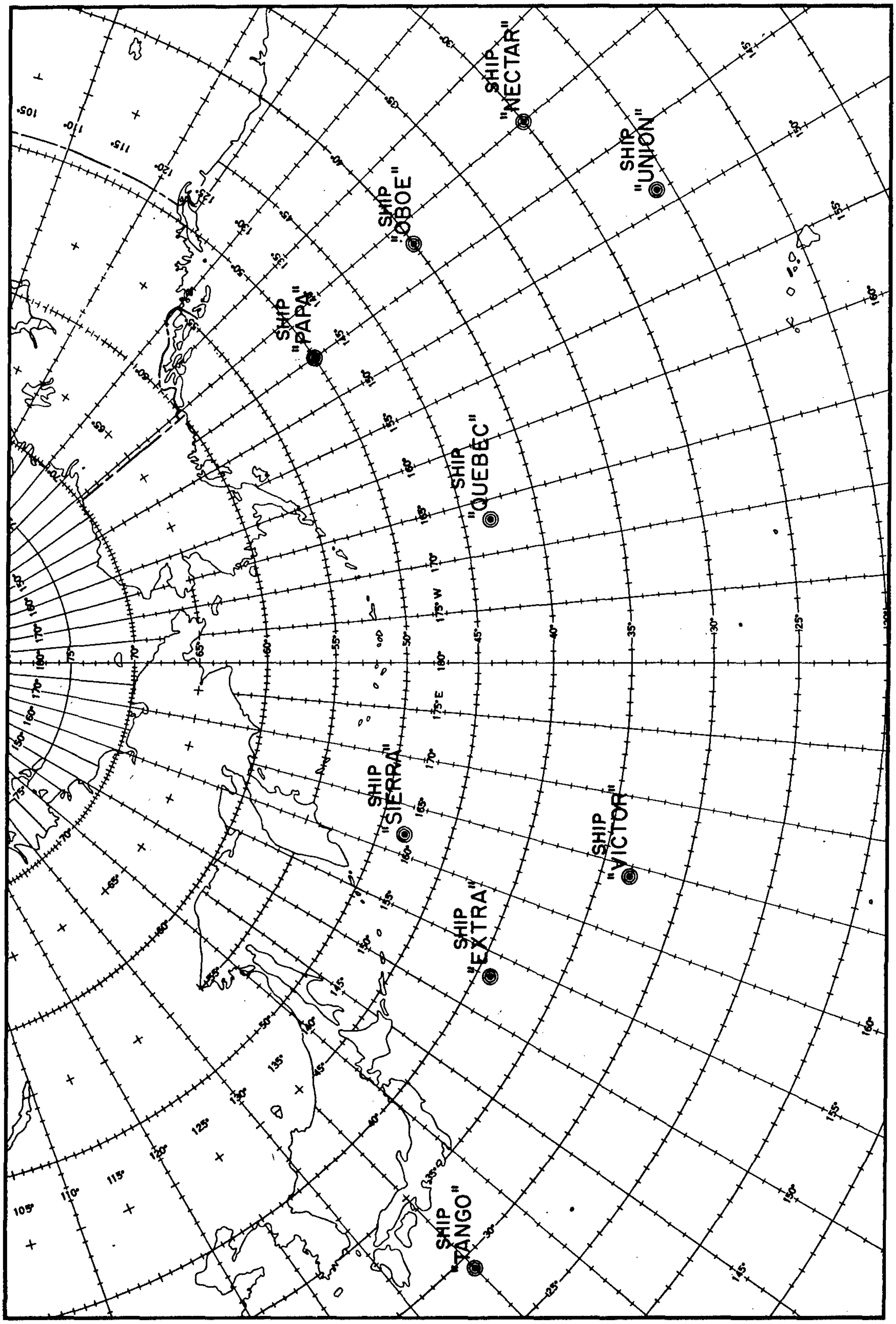


Figure 1.1. Map of the North Pacific Ship Locations.

The weather reported by each of such observations was classified according to criteria in table 1.3 as being favorable for or adverse to carrier air operations.

TABLE 1.3.
Criteria for Classification of Observations.

Favorable -	Not more than three (3) of the observed elements fall into the "marginal" classification of table 1.2, the other(s) being classified "operable."
Adverse -	One (1) or more of the observed elements fall into the "inoperable" classification of table 1.2, or four fall into the "marginal" classification.

1.3 Data Presentation

The data are presented in the form of two graphs. The curves on one graph were derived from seasonal frequency distributions of favorable and adverse weather periods. The other graph was developed from seasonal frequency distributions of individual allowance values calculated for each of the observations just described. Probabilities of desired occurrences are scaled, "Probability Percentage" on the vertical axis (ordinate) with "Duration" or "Individual Allowance" on the horizontal axis (abscissa). Applicable definitions and pertinent derivations are presented in paragraph 1.4. Comprehensive descriptions in chapter 2 and typical uses in chapter 3 should clarify the applications of the graphs.

1.4 Definitions and Derivations

Adverse - Adverse signifies any combination of meteorological and oceanographic parameters which severely restrict attack carrier operations. The parameters considered to be adverse are provided in tables 1.2 and 1.3.

Conditional Probability - Conditional probability in this publication refers to the probability, P(B/A), that event B will occur based upon the condition that event A already has transpired. P(B/A) may be given by,

$$P(B/A) = \frac{N(A \text{ and } B)}{N(A)}, \tag{1}$$

where among N(A), the number of occurrences in a sample of observed data giving rise to event A, N(A and B) is the number of occurrences giving rise to both event A and event B. Dividing both the numerator and denominator of equation 1 by N, the total number of occurrences (see the definition of probability below), yields,

$$P(B/A) = \frac{N(A \text{ and } B)/N}{N(A)/N} = \frac{P(A \text{ and } B)}{P(A)}, \tag{2}$$

in which P(A and B) is the probability that both events A and B will take place, and P(A) is the probability that event A will occur.

Duration - Duration denotes the length of time in hours during which a specified environmental or operational condition exists without change; e.g., for favorable weather conditions persisting $\underline{n}$ successive 3-hourly observations, the duration of the favorable condition is $\underline{3n}$ hours.

Favorable - Favorable indicates those combinations of meteorological and oceanographic parameters which do not restrict attack carrier air operations. These combinations are furnished in tables 1.1 and 1.2.

Individual Allowance - Individual allowance is the period between the arrival of a ship in an oceanic area and the end of a specified length of uninterrupted favorable weather in that location. Individual allowance is numerically equal to the waiting period plus the specified length of favorable weather. The term was derived from the fact that the individual allowance is the "a priori" estimate of the total time an individual ship or group of ships must allow (plan to spend in an area) in order to complete an operation requiring the specified unbroken period of favorable operating conditions.

Probability - Probability in this study indicates the degree of certainty that a desired event will occur based upon climatology. The probability, P(A), that event A will come about may be expressed mathematically by,

$$P(A) = \frac{N(A)}{N}, \tag{3}$$

where N(A) is the number of occurrences giving rise to event A in a sample of observed meteorological data and N is the total number of occurrences in the sample.

Season - Season signifies convenient subdivisions of the year. In this investigation the seasons are: Winter - December, January, February; Spring - March, April, May; Summer - June, July, August; and Fall - September, October, and November.

Waiting Period - Waiting period denotes the length of time between the arrival of a ship in an oceanic area and the beginning of a period of favorable weather of specified length in that locality.

2. GRAPH DESCRIPTIONS

2.1 Two Graph Types

For each of the nine Pacific Ocean stations shown in figure 1.1 and listed in table 1.1, the operational data are presented by seasons in two graph types.

Graph type I, illustrated by figure 2.1, consists of two curves which relate minimum durations of favorable weather (dashed curve) and adverse weather (solid curve) to their corresponding probabilities of occurrence. Sometimes for given values of duration the related probabilities are equal for both favorable and adverse situations, and consequently the two curves coincide at some points on the graph. Whenever such a state of affairs exists, a dotted line indicates the portions of the graph in which the duration curves are coincident. The vertical axis (ordinate) is scaled in "Probability Percentage" from zero to 100 percent, and the horizontal axis (abscissa) is "Duration" and ranges from zero to 350 hours. Graph type I may be used to answer the following questions:

1. Provided that the weather has just become favorable, a period of at least what length of favorable (or adverse) weather may be expected with a specified probability of occurrence?

2. What is the probability that a period of favorable (or adverse) weather once started will endure at least a preassigned period of time?

Graph type II, illustrated by figure 2.2, consists of five solid curves and a dashed line. The five solid curves arching upward to the right refer to operations requiring five specific lengths of uninterrupted favorable weather (i.e., 3, 12, 24, 48, and 72 hours), and each is labeled appropriately. Like graph I, the ordinate depicts "Probability Percentage," however, the abscissa portrays "Individual Allowance" values scaled from zero to 420 hours. See definition of individual allowance in paragraph 1.4. The probability of a specified favorable period falling within a desired allowable time on station may be ascertained from the appropriate curve. The dashed line sloping downward toward the right is the locus of the initial points of the operation curves described above. This line on a given graph, type II, yields probabilities of obtaining specified lengths of favorable weather immediately upon arrival of a vessel in the operational locality of interest when local conditions are favorable. Thus, for any point on the dashed curve the individual allowance equals the operational period.

The weather records used to construct the graphs sometimes contained observations either recorded incompletely or not at all. Two methods were employed in order to estimate suitable operational classifications for the unobserved weather prevailing at such observation times. Low ceilings frequently occur simultaneously with low visibilities, thus forming a pair of dependent elements. High winds often coexist with high seas which constitute another pair of related parameters. The first technique entailing such interdependence was applied whenever either element in either interrelated pair was absent. The second method consisted of assigning synthetic data to breaks in the sequence and was employed when observations were so incomplete as to preclude using actual data. The data were synthesized in such a manner that synthesized sequences has statistical characteristics closely approaching those of actual data sequences. Consequently, the completed graphs depict parameter values nearly equal in most cases to those obtained had the data been complete. However, in rare instances where existing data were insufficient to permit reliable synthetic sequences to be made, graphs could not be constructed. These are labeled "Adequate Data Unavailable" in chapters 4 and 5.

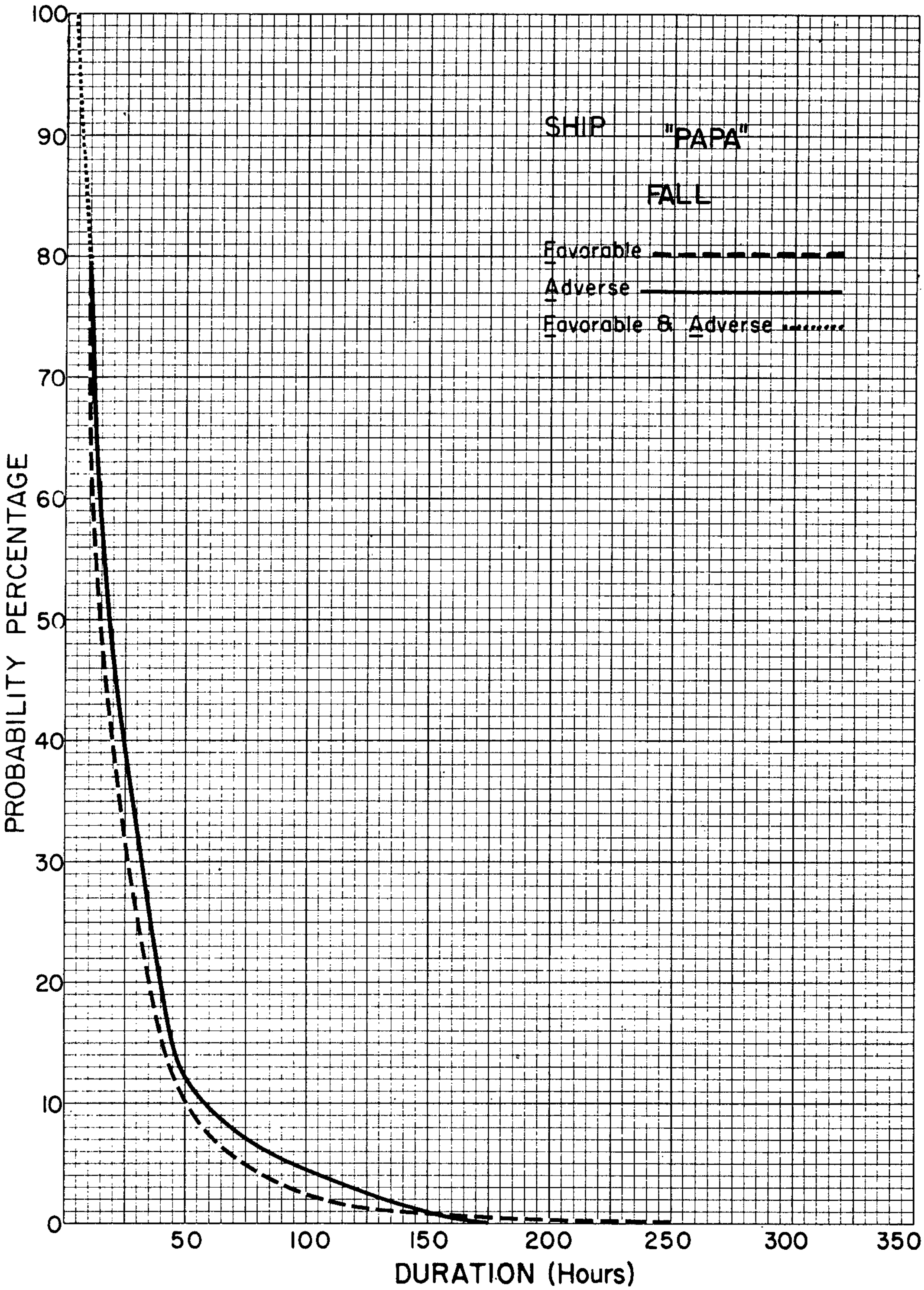


Figure 2.1. Probable Duration of Favorable and Adverse Operational Weather for Ship "Papa" - Fall (Graph Type I).

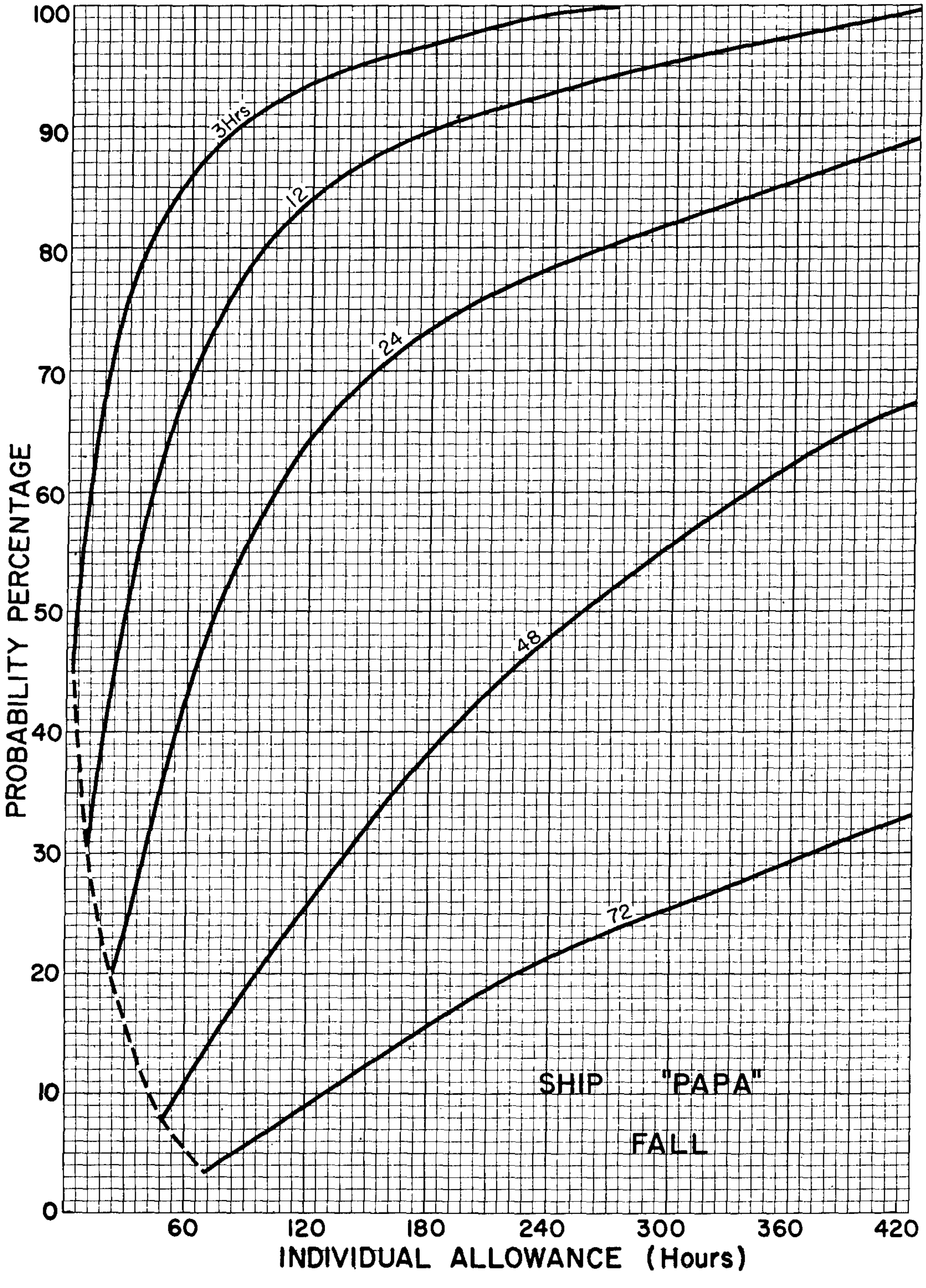


Figure 2.2. Probable Individual Allowances for Operations of Specific Durations for Ship "Papa" - Fall (Graph Type II).

3. GRAPHICAL APPLICATIONS

3.1 Purpose of Examples

Typical problems and their solutions are offered as a reference. Every example in this chapter refers to the ship "Papa" area (see fig. 1.1), fall season. However, the methods involved need not be restricted thereto, but may be applied to other given Pacific localities and seasons as well.

3.2 Selected Applications of Graph Type I

3.2.1 Utilizing Graphical Information Read Directly

Example 1. Planning requiring favorable weather.

Problem 1.

For transit through the ship "Papa" area in the fall season favorable weather is required. Given that the weather has just become favorable, calculate the probability that such conditions will continue for at least 12 hours. In addition, determine the probability of the favorable conditions enduring less than 12 hours.

Solution:

Consult the appropriate graph (i.e., fig. 2.1) and focus attention on the favorable weather (dashed) curve. Read the ordinate value corresponding to the intersection of the dashed curve and the 12 hour duration line. The value thus extracted indicates that the probability is 58 percent that favorable conditions once commencing will persist at least 12 hours. In order to calculate the probability of the favorable conditions prevailing less than 12 hours under the stated conditions, subtract 58 percent from 100 percent. Hence, the required probability of adverse weather recurring sometime within the 12 hour period is 42 percent.

Problem 2.

For planning purposes the commencing time of favorable weather will be known, and the commander will accept a probability of 82 percent that such conditions will hold. How long may favorable weather conditions be expected to persist given this probability?

Solution:

In problem 1 above reverse the procedure indicated. The intersection of the 82 percent probability line and the dashed favorable weather curve indicates that at least 8 hours of uninterrupted weather may be expected.

Example 2. Planning involving adverse weather.

The procedures indicated in example 1 above may be applied to planning movements requiring adverse weather. Merely, substitute the words "adverse" and "solid" for "favorable" and "dashed" in the text and proceed as otherwise directed.

3.2.2 Special Probability Problems

Example 1. Calculating the probability of weather remaining favorable for a specific period after being favorable for a known duration.

Problem 1.

Given that the weather became favorable 12 hours prior, calculate the probability of the favorable weather remaining at least the following 24 hours, and the probability that adverse weather will recur sometime during the ensuing 24 hour interval.

Solution:

In a given collection of observed favorable weather periods which persist at least D_P hours, a certain number of them will extend an additional D_N hours. Dividing this number by the sum of the periods in the group which endure at least D_P hours yields the conditional probability, $P(D_N)$, (see paragraph 1.4) that weather having become favorable D_P hours prior, will prevail at least another D_N hours. Thus, $P(D_N)$ may be expressed for calculation by,

$$P(D_N) = \frac{P(D_P + D_N)}{P(D_P)} , \tag{4}$$

where $P(D_P)$, taken from the graph, is the probability that weather conditions after becoming favorable will endure at least D_P hours (see example 1, problem 1 above). $P(D_P + D_N)$, also taken from the graph, is the prob-

ability of the favorable weather persisting a total period of at least $D_P + D_N$ hours.

From equation 4, $P(D_N)$ may be calculated for the given problem in the form,

$$P(\text{next } 24) = \frac{P(\text{total } 36)}{P(\text{past } 12)} = \frac{.20}{.58} = 34\% .$$

Q(next 24), the probability that the favorable weather will revert to adverse sometime during the following 24 hours, may be calculated by;

$$Q(\text{next } 24) = 100 - P(\text{next } 24) = 100 - 34 = 66\%.$$

Example 2. Calculating the probability that weather after becoming favorable will endure at least a specified period but not longer than some other specified period.

Problem 1.

During fall at ship "Papa" the weather improved. What is the probability of the favorable weather reverting to adverse sometime during the time-interval between 6 and 18 hours after the improvement came about?

Solution:

A certain percentage of a selected sample of observed favorable weather periods endures for periods of at least D_A hours, and another percentage endures at least D_B hours. The difference between these percentages is the percentage of periods in the sample enduring at least D_A hours but not more than D_B hours. Consequently, such a difference provides the probability, $P(D_B - D_A)$, that a period of weather once becoming favorable will prevail at least D_A hours but not longer than D_B hours. Thus, $P(D_B - D_A)$ may be expressed by,

$$P(D_B - D_A) = P(D_A) - P(D_B) , \qquad (5)$$

where $P(D_A)$ and $P(D_B)$ are probability percentages extracted individually from an appropriate graph, type I. These two quantities are probabilities that environmental conditions after becoming favorable will endure at least D_A hours and D_B hours respectively.

Applying equation 5 to the stated problem, $P(D_B - D_A)$ may be calculated in the manner,

$$P(D_{18} - D_6) = P(D_6) - P(D_{18}) = 92 - 42 = 50\%.$$

Example 3. Special probability problems involving adverse weather.

The words "favorable" and "adverse" in examples 1 and 2 above may be interchanged and the statements will be valid. Under these conditions the values of $P(D_N)$ and $P(D_B - D_A)$ are 35 percent and 43 percent, respectively.

3.3 Selected Applications of Graph Type II

Example 1. Length of waiting period to operate for a specified duration with adverse weather on arrival.

Problem 1.

Given that adverse weather is discovered upon arrival in the ship "Papa" area, fall season, determine the probability that the maximum waiting period anticipated (see paragraph 1.4) will be no longer than 18 hours before the weather turns favorable and remains favorable sufficiently long to complete an operation of 12 hours.

Solution:

Consult the appropriate graph depicting individual allowance versus probability percentage (i.e., fig. 2.2) and concentrate upon the 12 hour operation curve. Read the ordinate value pertaining to the intersection of the 12 hour curve and the 30 hour (18 + 12) individual allowance line. The probability required is 50 percent that a 12 hour length of favorable operating weather will occur sometime within 30 hours allowable time on station.

Problem 2.

A planned operation in the ship "Papa" region in fall specifies that a carrier arrive in the area employing adverse weather as a cover, operate aircraft 24 hours, and depart. The ship is assumed able to reach the area under adverse weather conditions according to a current forecast. Other planning considerations dictate that a probability less than 50 percent of obtaining 24 hours of uninterrupted weather within 84 hours allowable time on station will curtail planning and cancel the operation. Will planning proceed under these conditions?

Solution:

Applying the procedure above in problem

1 and the 24 hour operation curve in figure 2.2, the probability corresponding to an individual allowance of 84 hours is 54 percent. Because 54 percent exceeds 50 percent planning will continue.

Example 2. Probability of favorable weather persisting for a specified period providing favorable weather exists upon arrival.

Problem 1.

Favorable weather exists upon arrival in the operating area. The time at which it became favorable is unknown. Ascertain the probability of obtaining uninterrupted favorable weather for the subsequent 12 hours, in order to initiate immediately and successfully complete a task force manuever.

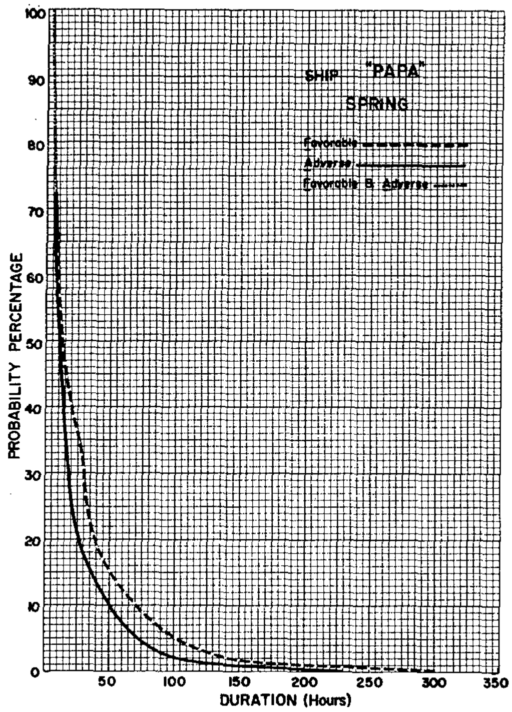
Solution:

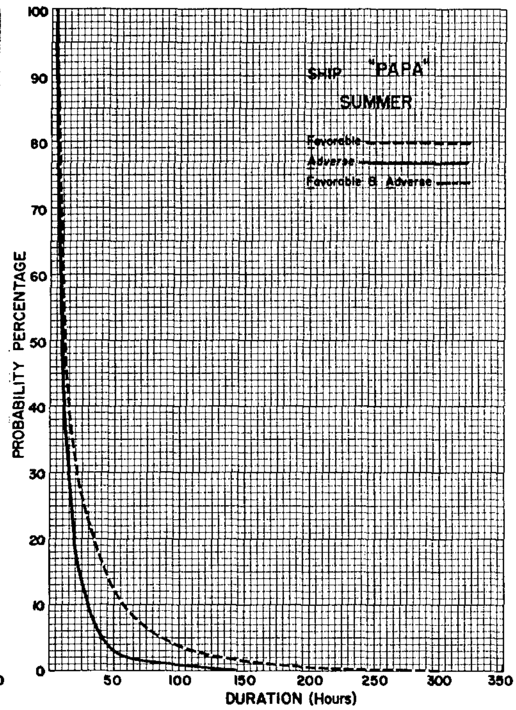
Consult the appropriate graph (fig. 2.2). Read the ordinate value related to the intersection of the dashed line arching downward to the right and the initial point of the 12 hour operation curve. The desired probability is 31 percent.

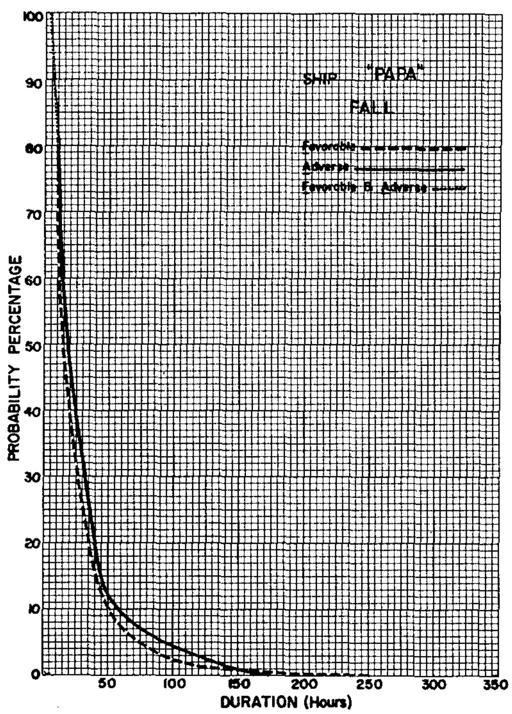
4. GRAPHS - TYPE I

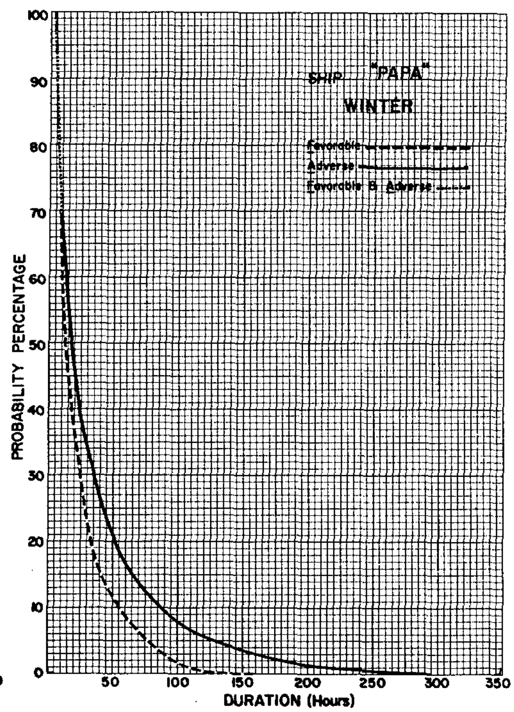
4.1 Probable Durations of Favorable and Adverse Operational Weather for North Pacific Ship Stations

4.1.1 "Papa" - Spring, Summer, Fall, Winter









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Example 2. Probability of favorable weather persisting for a specified period providing favorable weather exists upon arrival.

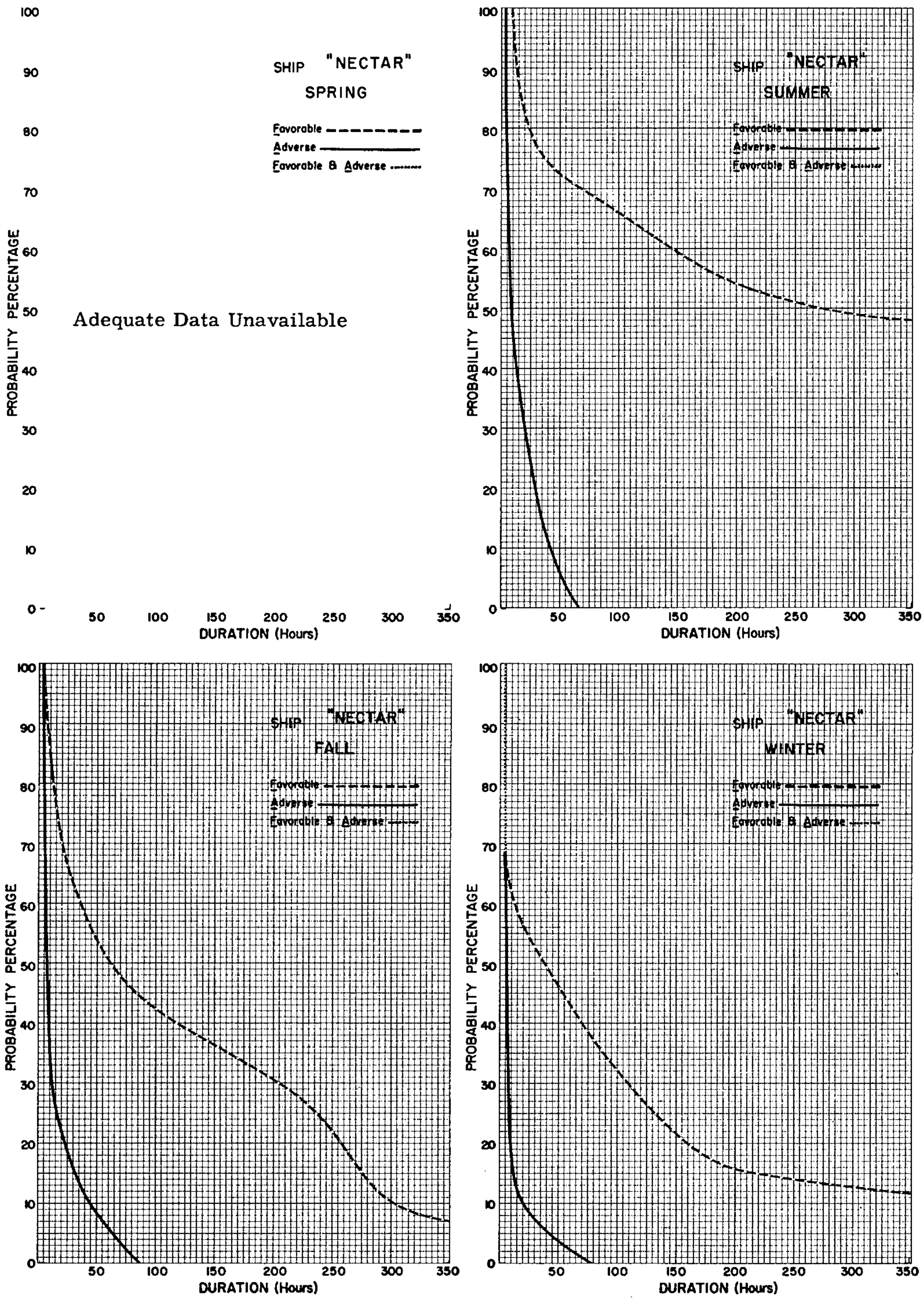
Problem 1.

Favorable weather exists upon arrival in the operating area. The time at which it became favorable is unknown. Ascertain the probability of obtaining uninterrupted favorable weather for the subsequent 12 hours, in order to initiate immediately and successfully complete a task force manuever.

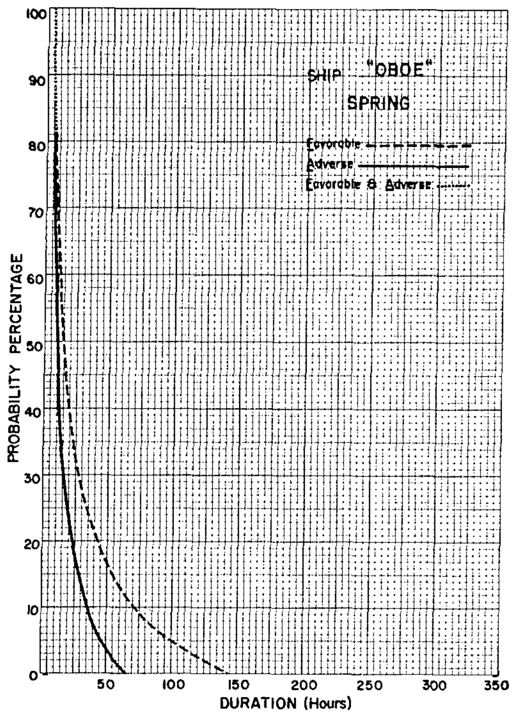
Solution:

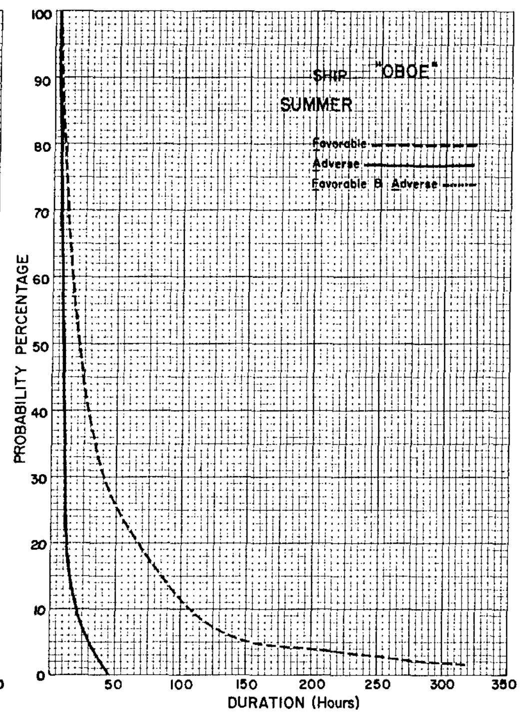
Consult the appropriate graph (fig. 2.2). Read the ordinate value related to the intersection of the dashed line arching downward to the right and the initial point of the 12 hour operation curve. The desired probability is 31 percent.

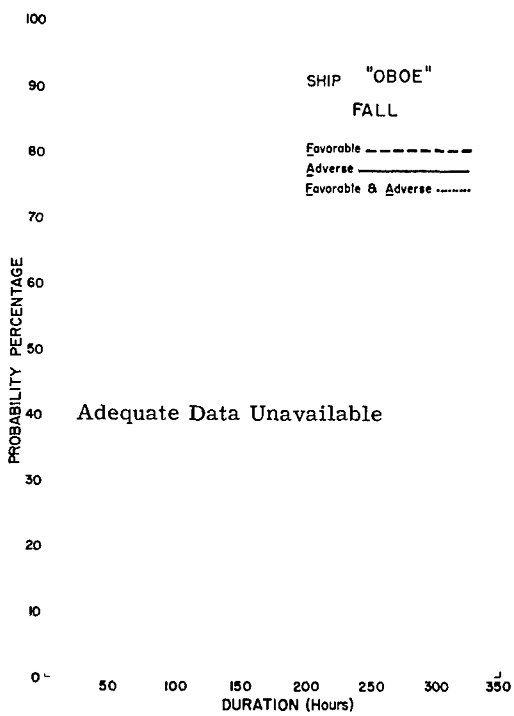
4.1.2 ''Nectar'' - Spring, Summer, Fall, Winter

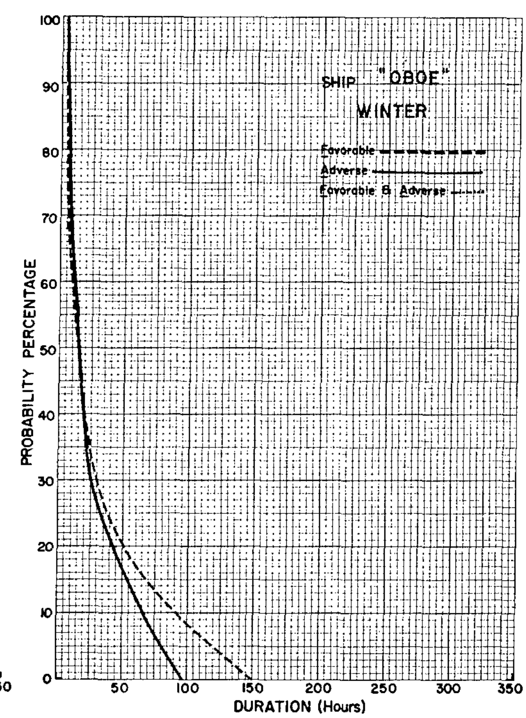


4.1.3 "Oboe" - Spring, Summer, Fall, Winter

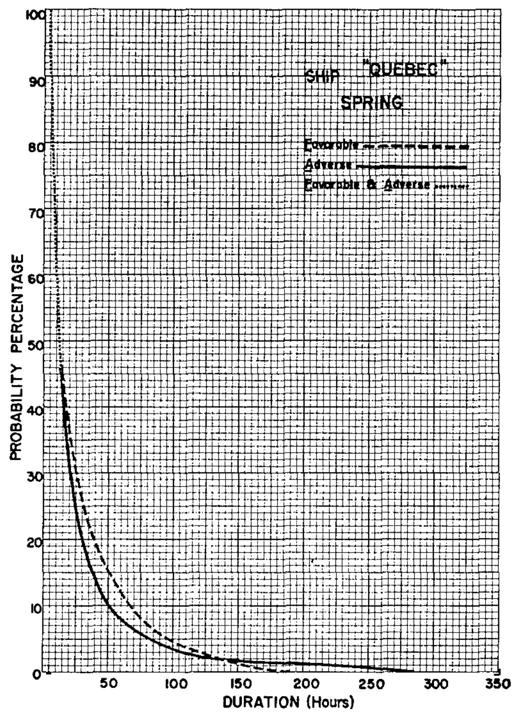


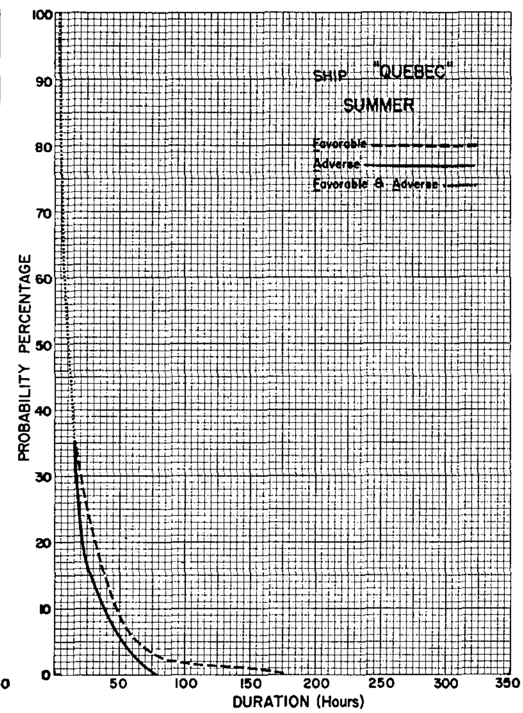


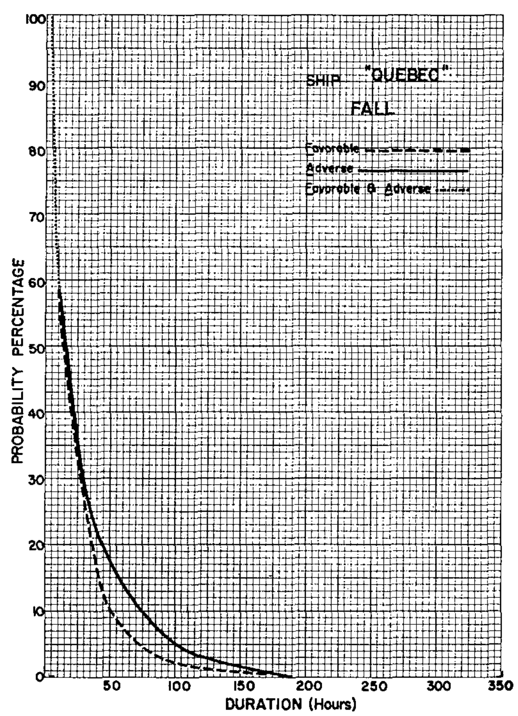


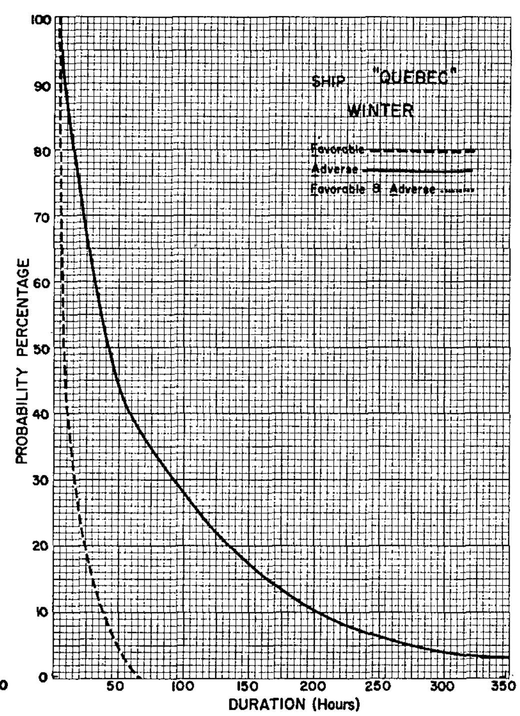


4.1.4 ''Quebec'' - Spring, Summer, Fall, Winter

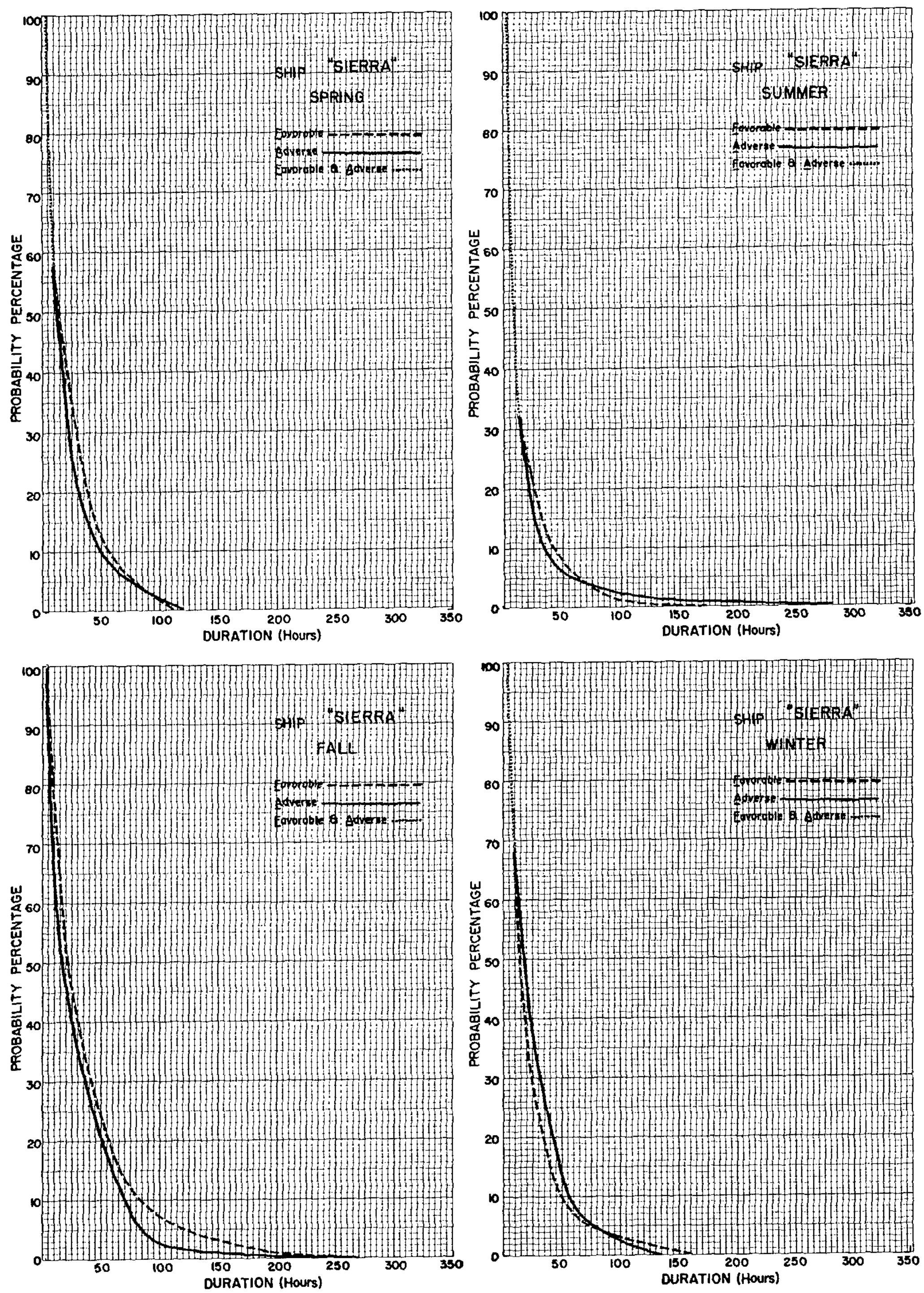




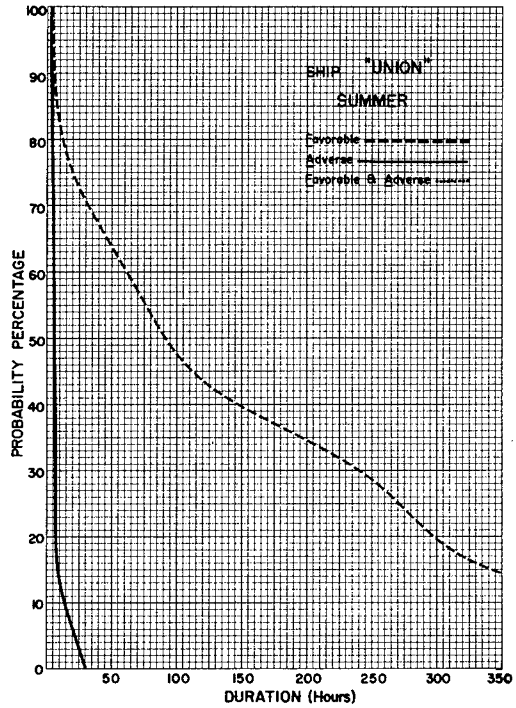


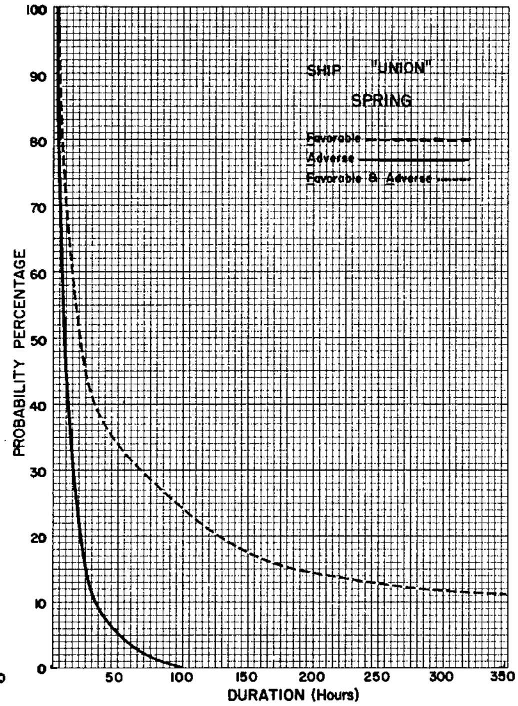


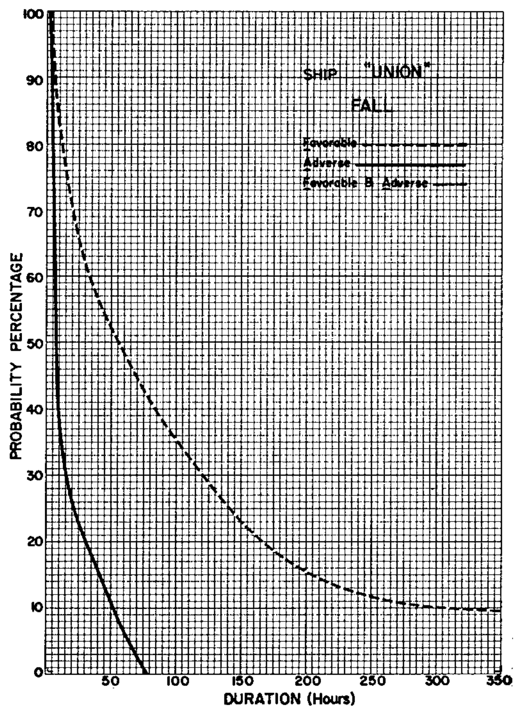
4.1.5 "Sierra" - Spring, Summer, Fall, Winter

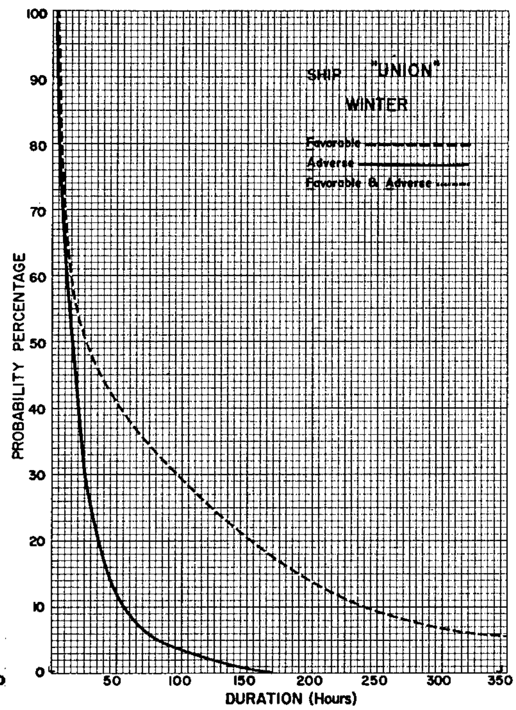


4.1.6 "Union" - Spring, Summer, Fall, Winter

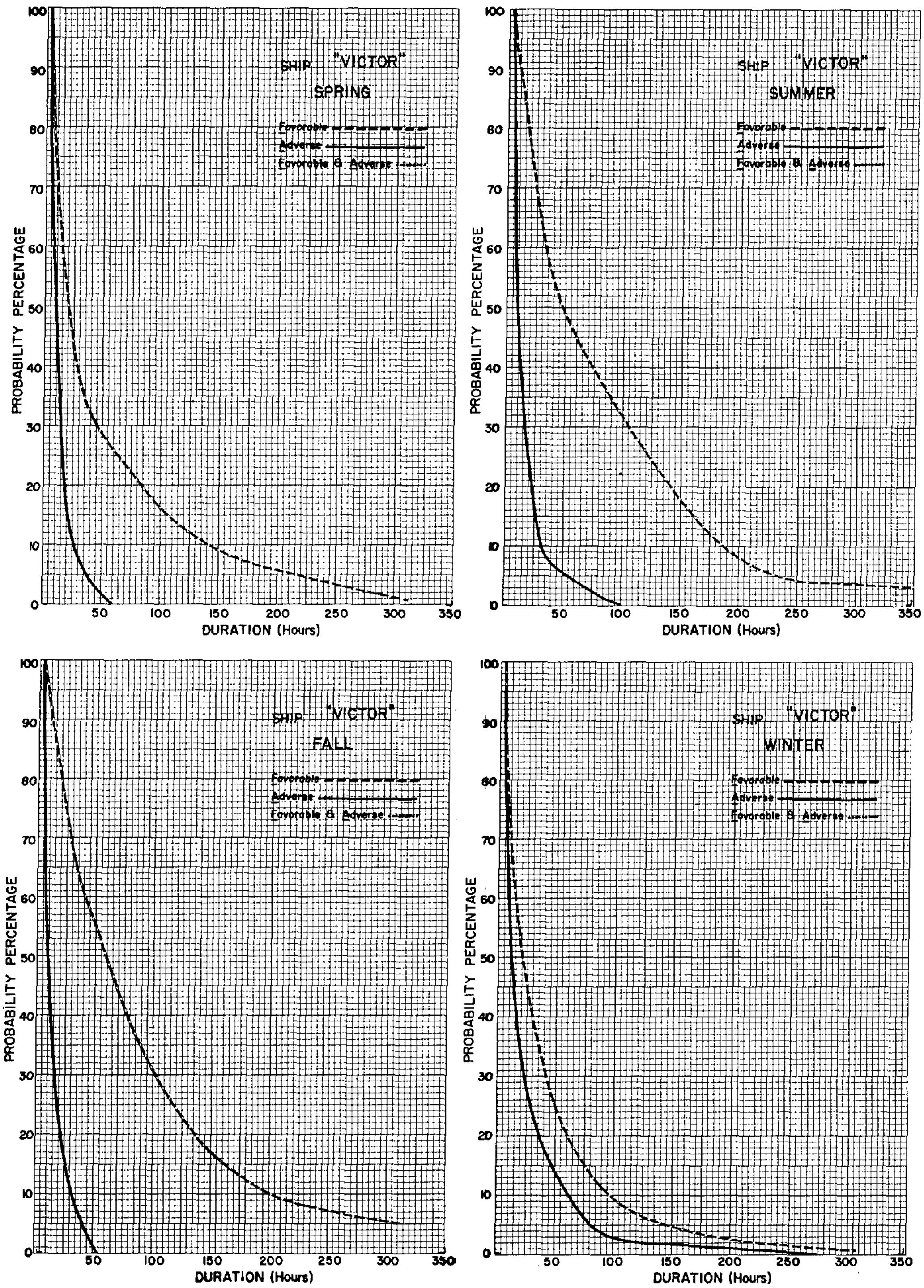




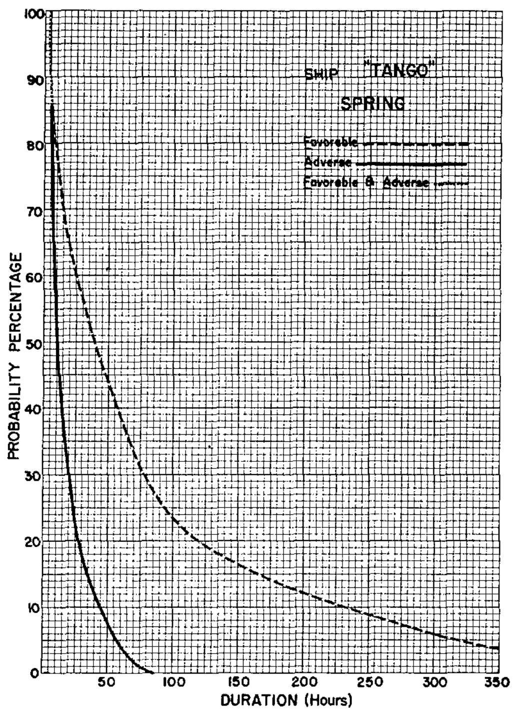


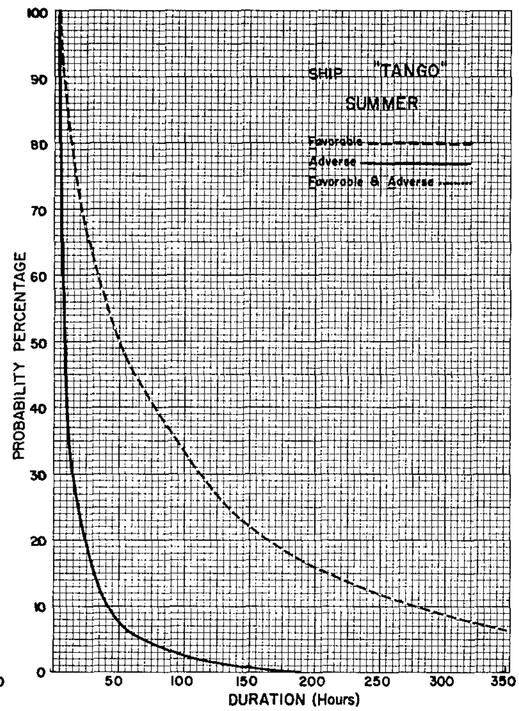


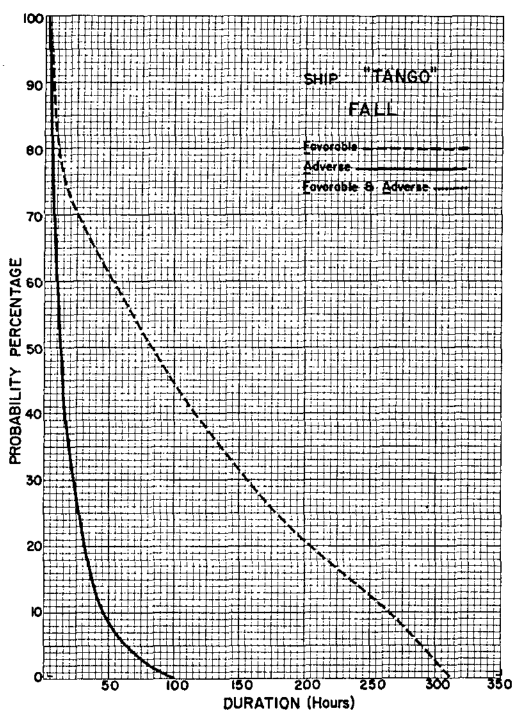
4.1.7 "Victor" - Spring, Summer, Fall, Winter

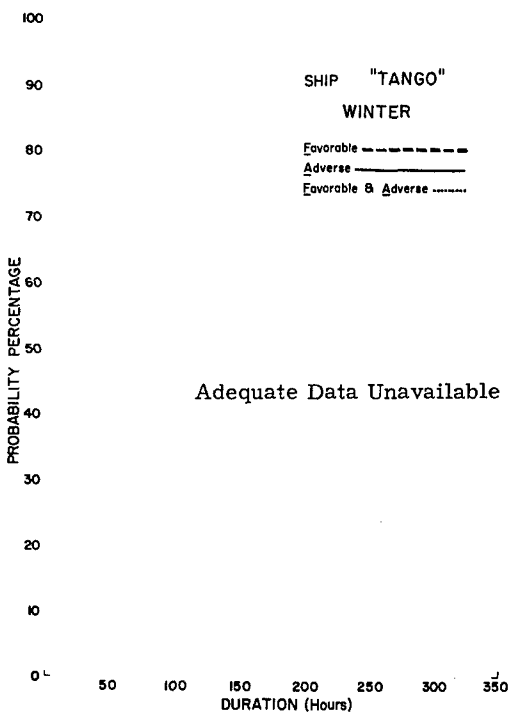


4.1.8 "Tango" - Spring, Summer, Fall, Winter

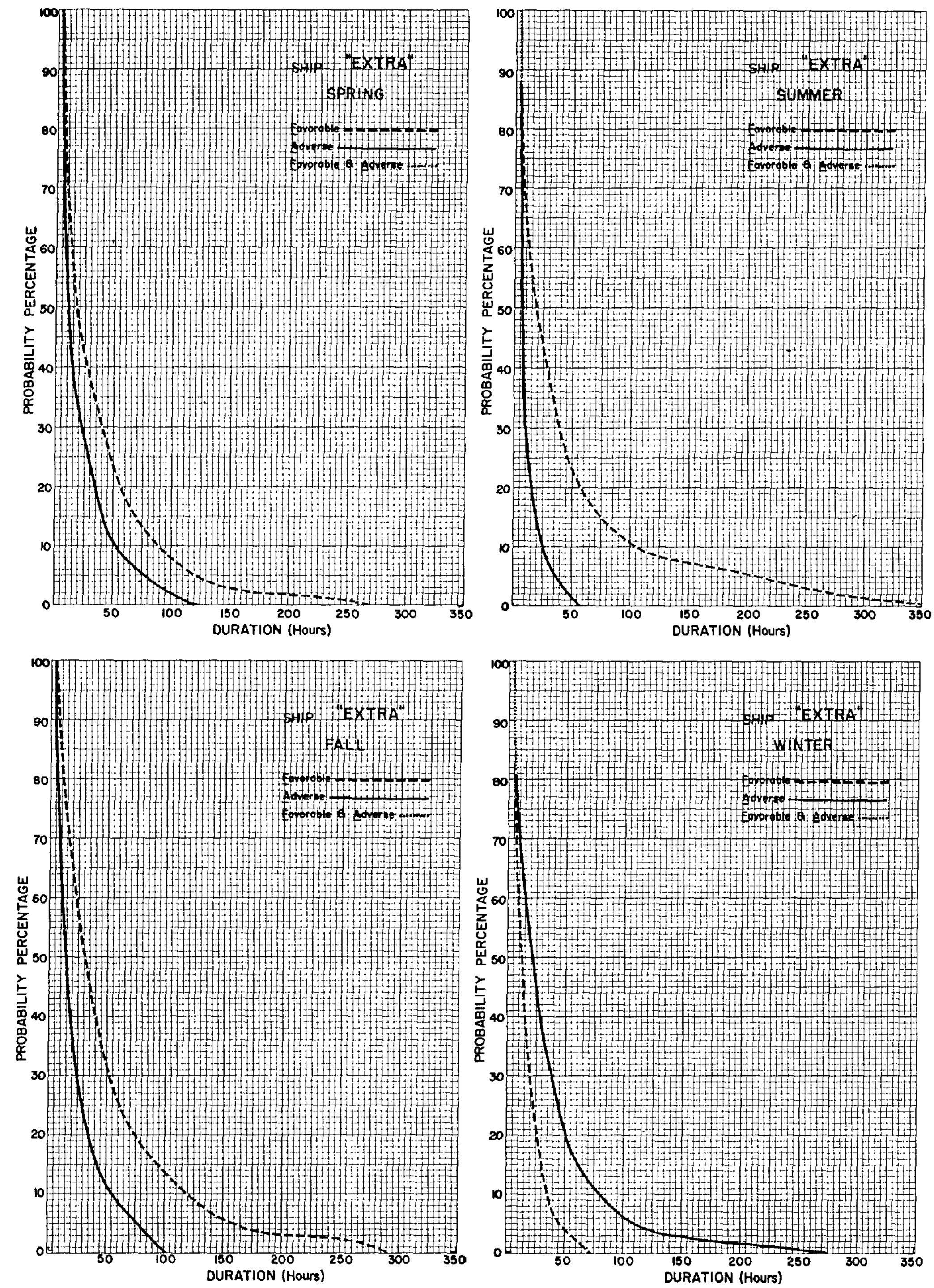








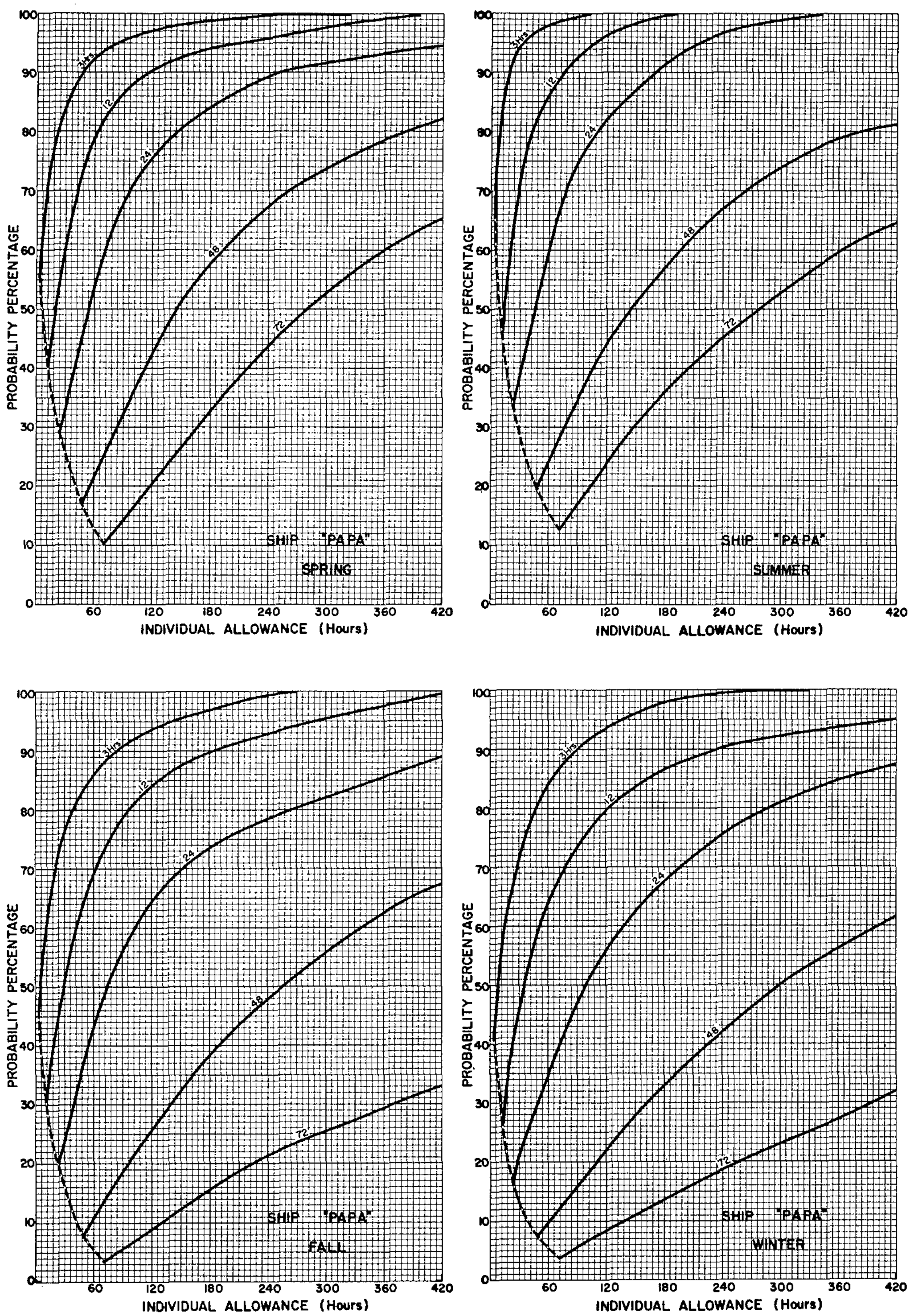
4.1.9 ''Extra'' - Spring, Summer, Fall, Winter



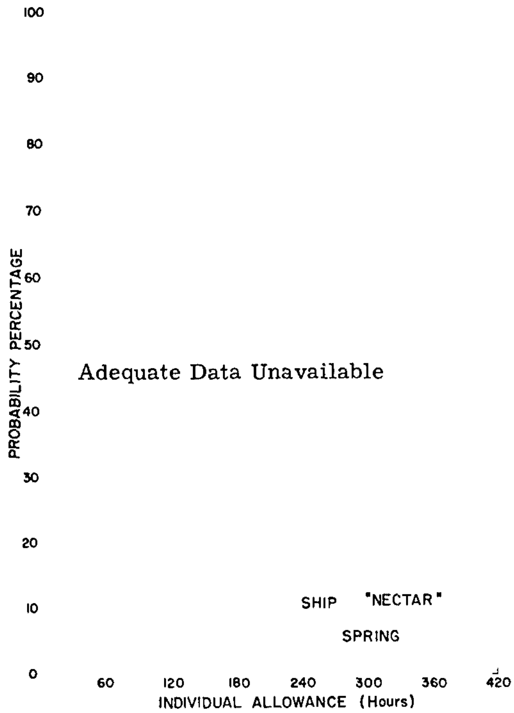
5. GRAPHS - TYPE II

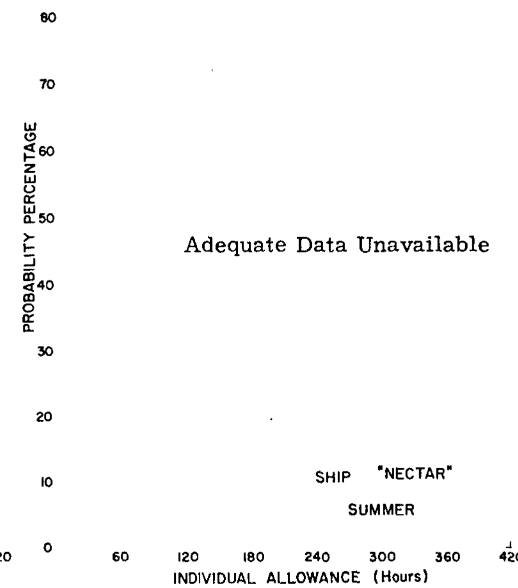
5.1 Probable Individual Allowances for Operations of Specific Durations for North Pacific Ship Stations

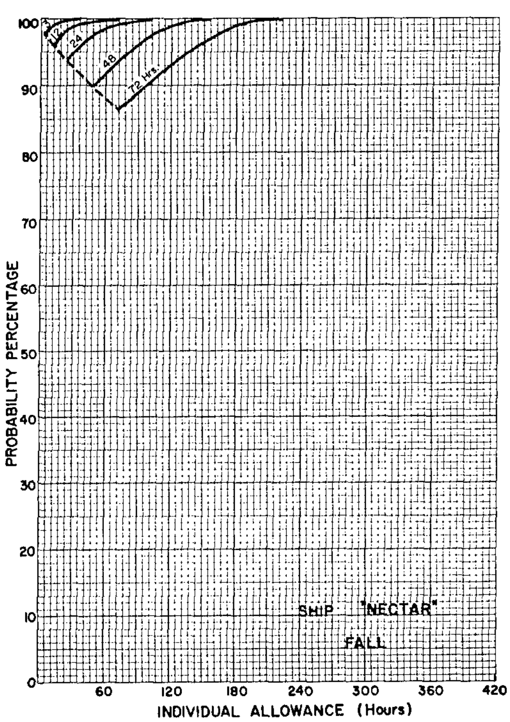
5.1.1 "Papa" - Spring, Summer, Fall, Winter

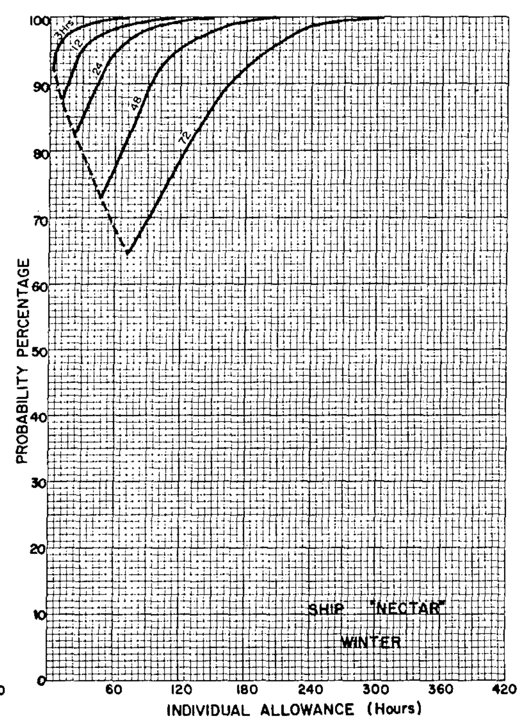


5.1.2 ''Nectar'' - Spring, Summer, Fall, Winter

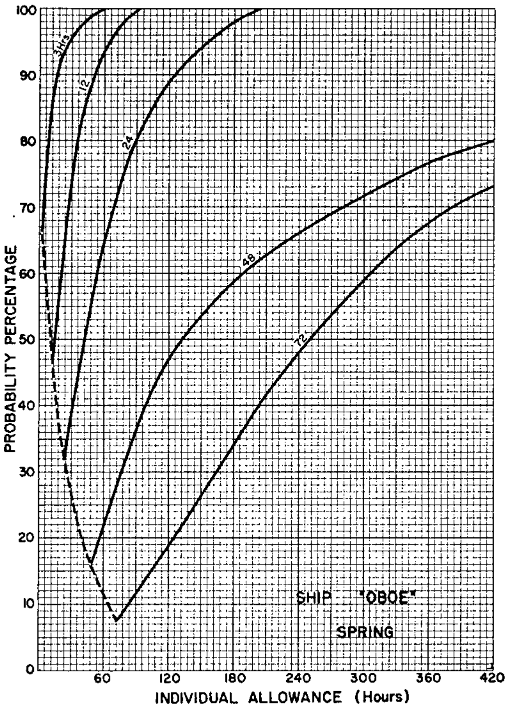


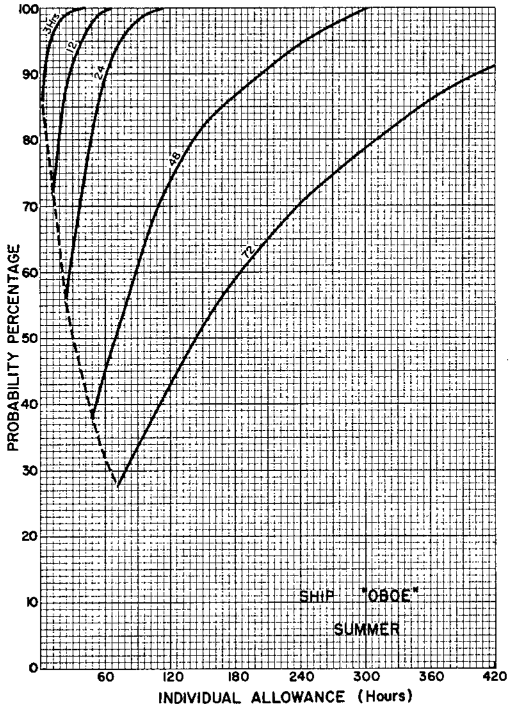






5.1.3 "Oboe" - Spring, Summer, Fall, Winter





PROBABILITY PERCENTAGE

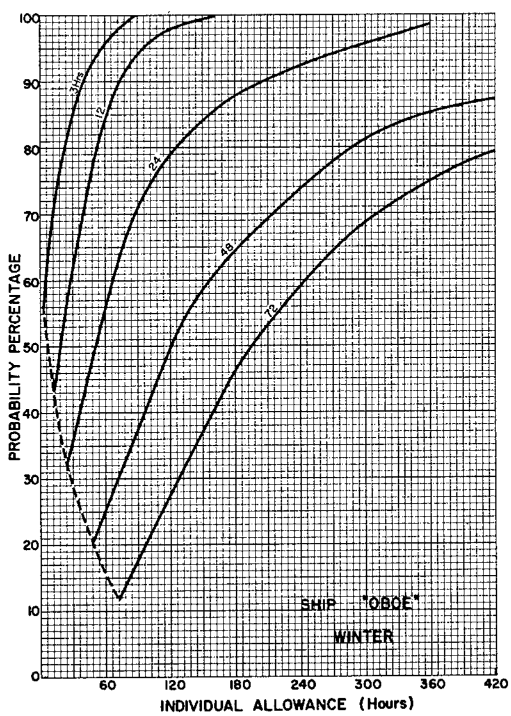
Adequate Data Unavailable

SHIP "OBOE"

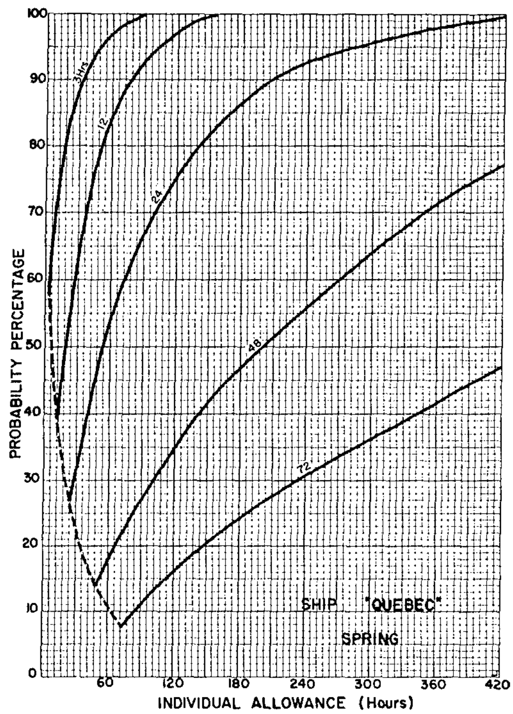
FALL

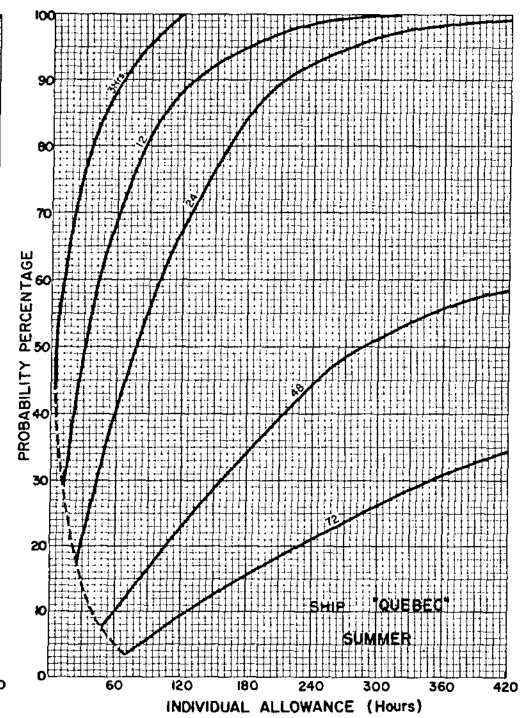
0 60 120 180 240 300 360 420

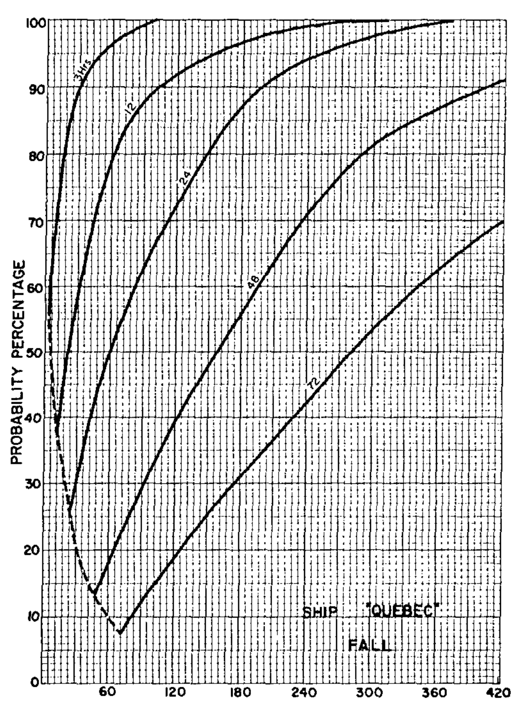
INDIVIDUAL ALLOWANCE (Hours)

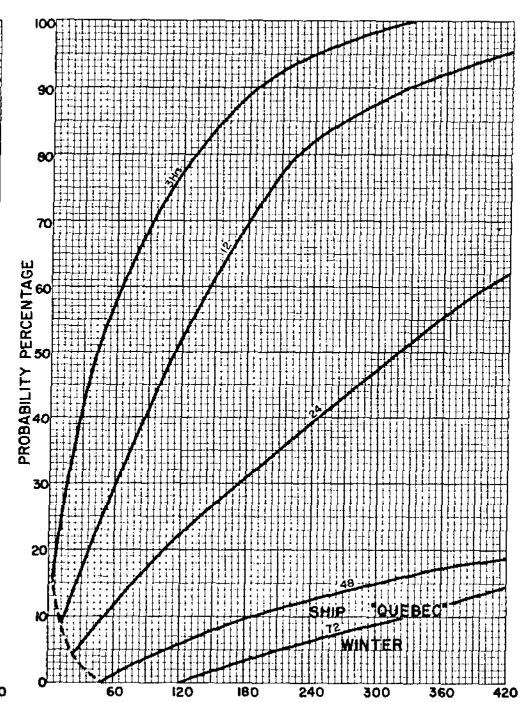


5.1.4 "Quebec" - Spring, Summer, Fall, Winter

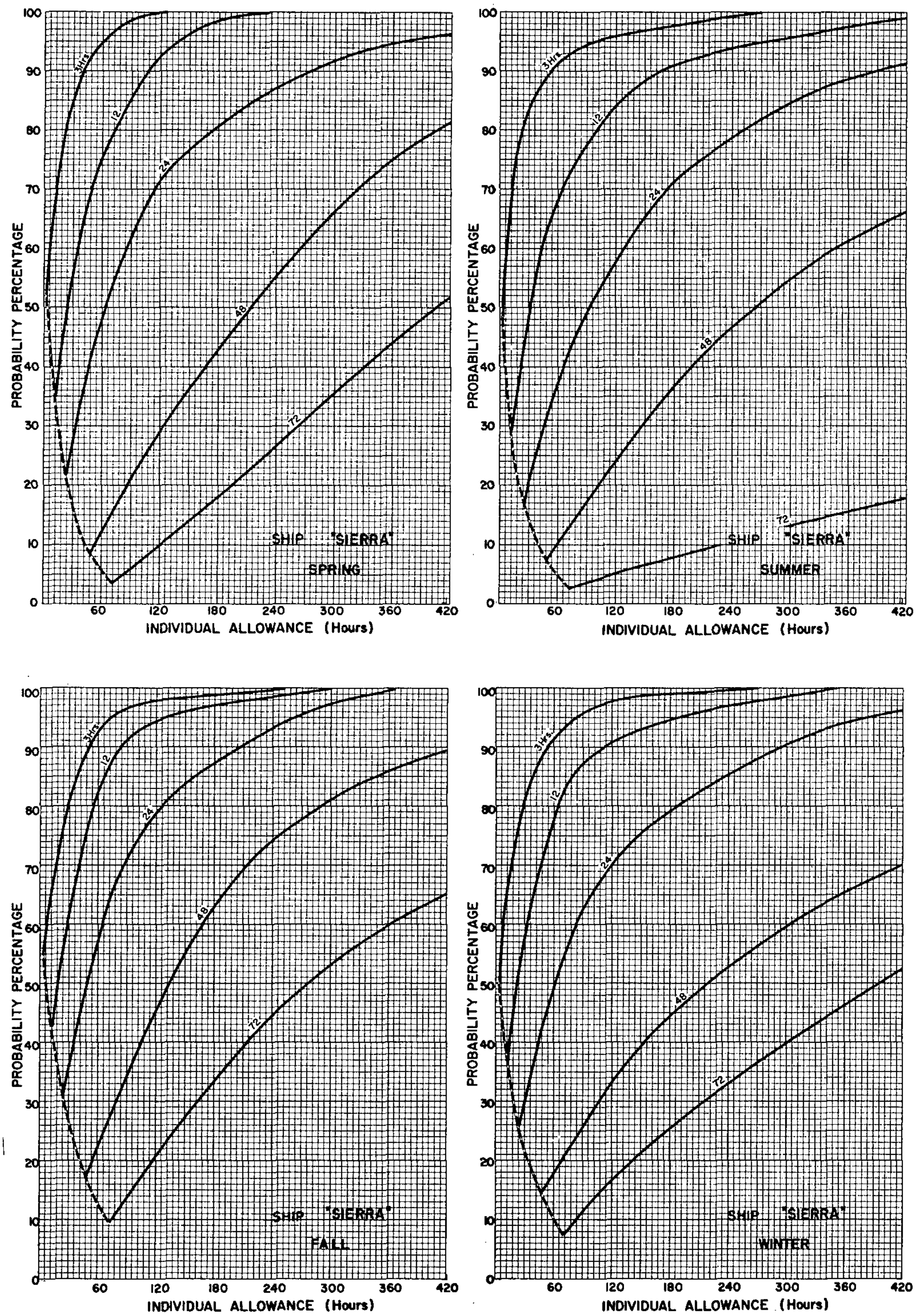




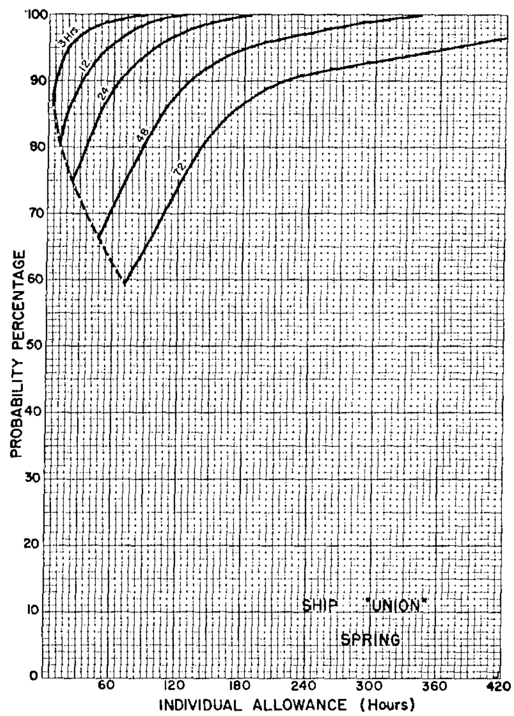


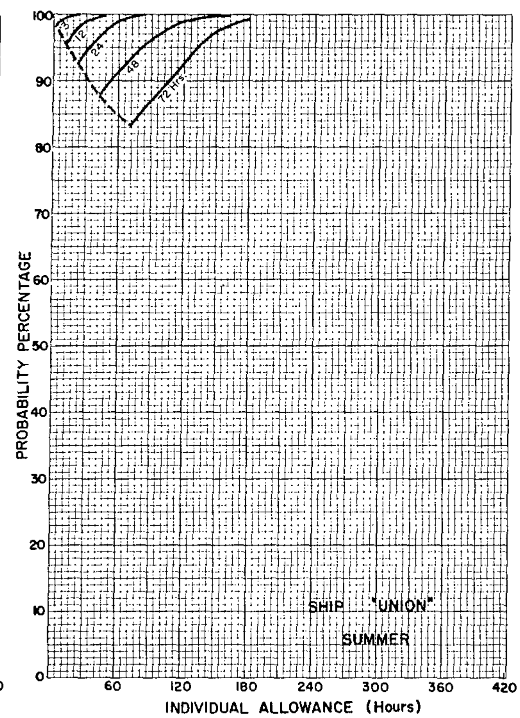


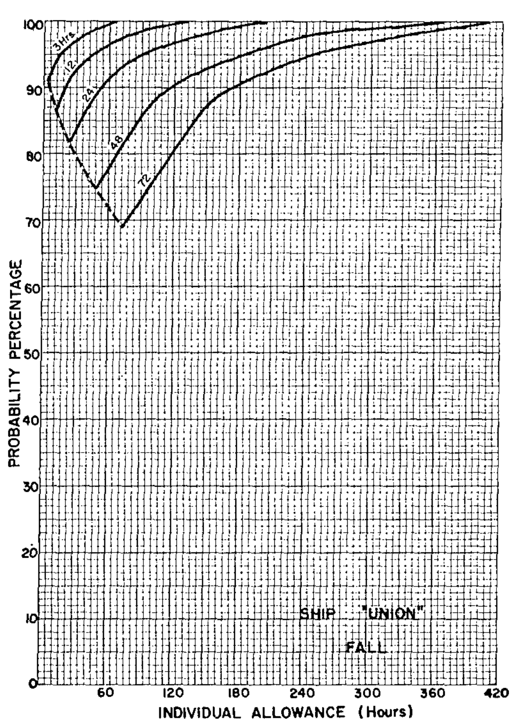
5.1.5 "Sierra" - Spring, Summer, Fall, Winter

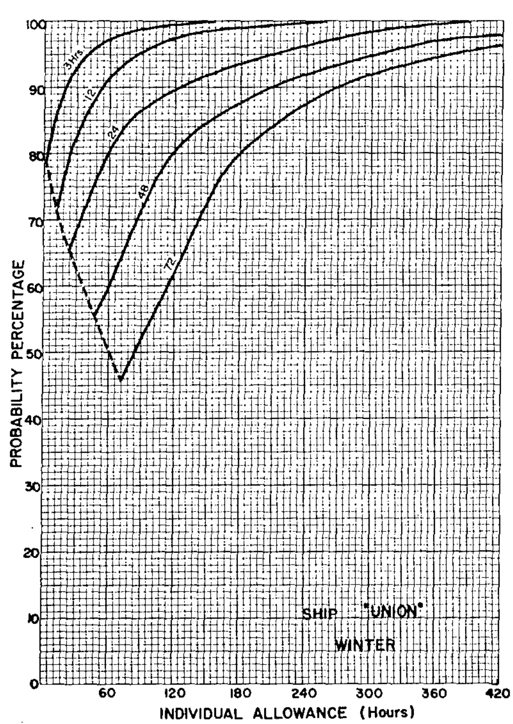


5.1.6 "Union" - Spring, Summer, Fall, Winter

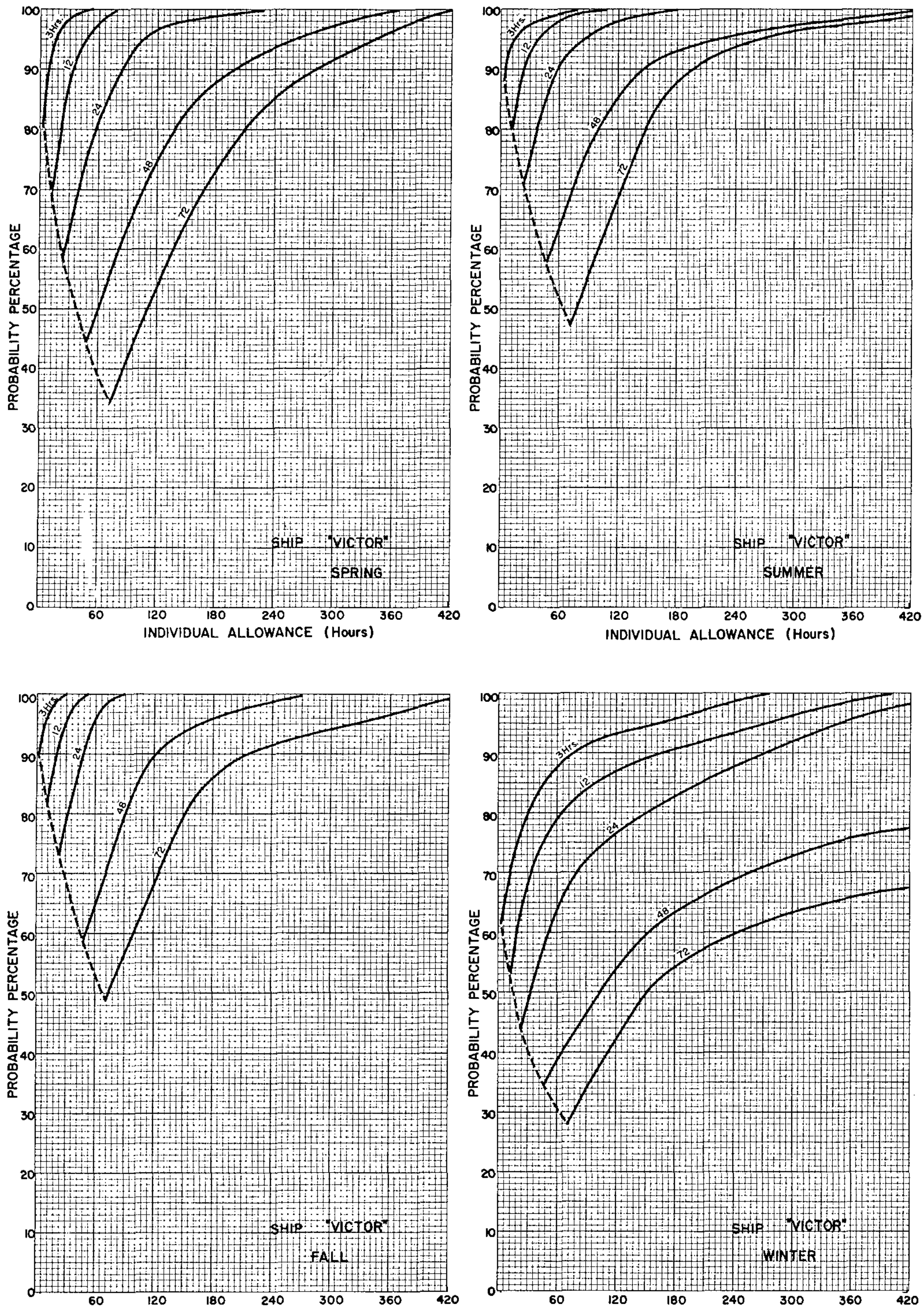




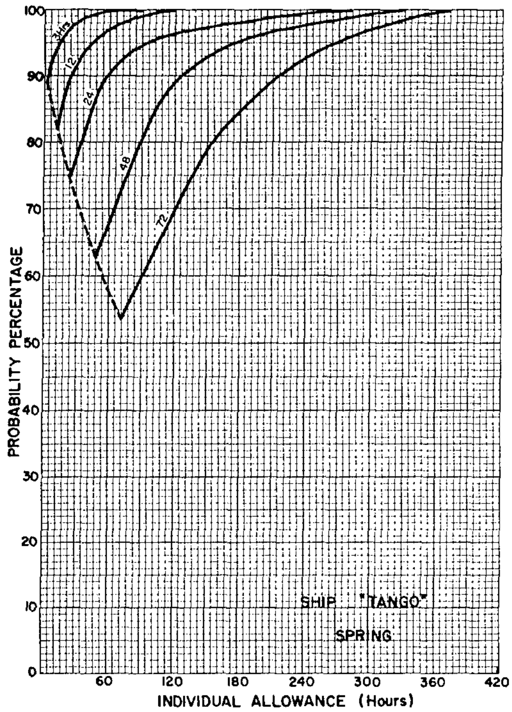


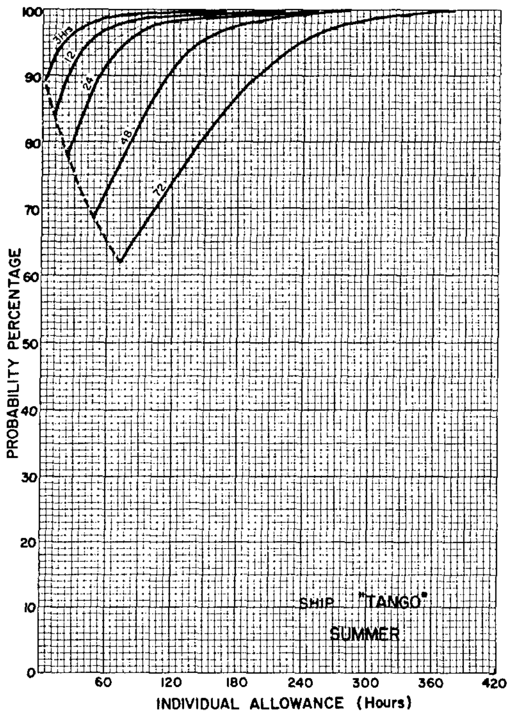


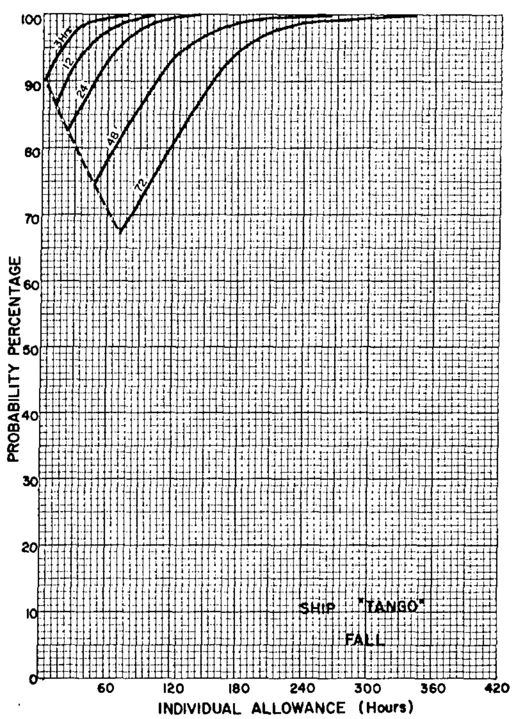
5.1.7 "Victor" - Spring, Summer, Fall, Winter

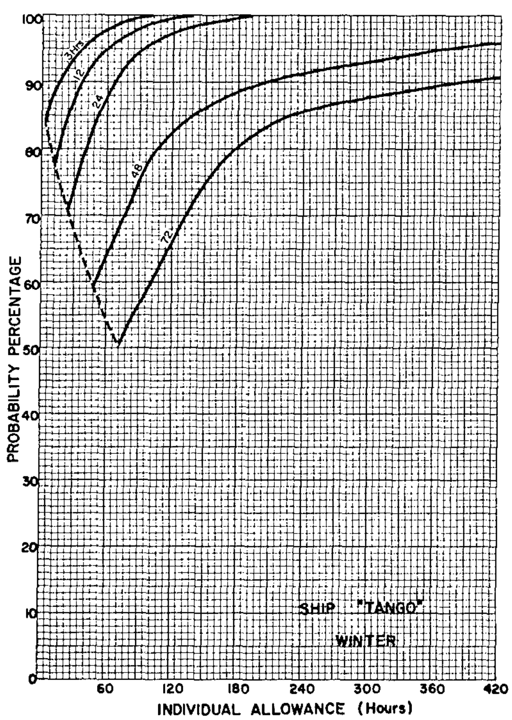


5.1.8 "Tango" - Spring, Summer, Fall, Winter









5.1.9 "Extra" - Spring, Summer, Fall, Winter